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# The fecundity of the Atlantic salmon (Salmo salar L.) from the Varguza River

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The literature does contain brief information about the fecundity of the Atlantic salmon, but in the majority of cases, determination of fecundity was carried out on the basis of limited material and during one particular season (Novikov, 1936, 1953, 1956; Gorsky, 1935; Smirnov, 1935; Nikol'sky et al., 1947; Gulyayeva, 1950; Hutton, 1949). The number of Varguza Atlantic salmon at the breeding grounds can be estimated from the data of the control station, or determined analytically (Melnikova, 1958), having simultaneously established the percentage of the yield of Atlantic salmon to the fishery in relation to the number of eggs deposited. We must know the fecundity of this fish in order to accomplish this.

The Atlantic salmon of the Varguza R. is grouped into "winter salmon" (enters the river in June), "summer salmon" (enters the river at the end of June or beginning of July), grilse (July),

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*The numbers in the right-hand margin are the pages of the Russian text - translator

and autumn salmon (enters the river mainly in October-November) (Melnikova, 1959). Since females of the autumn salmon sharply predominate in the Varguza R. and the abundance of female grilse and summer salmon constituted approximately 4% of the number of female autumn salmon in 1958 and 2.3% of the same in 1959, the data presented in this paper characterize mainly the fecundity of this particular group.

The average dimensions of autumn Atlantic salmon vary during the different years, and throughout the season (table 1). The estimates are based on the data of fishery statistics gathered by per unit and weight calculations. With the exception of certain years, the weight of the autumn salmon at the onset of migration (September) is somewhat greater than at the end of it (November).

Table 1. Average monthly weight (kg) of autumn Atlantic salmon from the Varguza River

| Month | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 |
|---|---|---|---|---|---|---|---|
| September | 2.8 | 3.4 | 3.2 | 2.6 | 3.7 | 3.0 | 2.6 |
| October | 2.6 | 2.6 | 3.2 | 2.6 | 2.8 | 3.0 | 2.5 |
| November | 2.7 | 2.5 | 2.9 | 2.5 | 2.6 | 2.9 | 2.7 |
| Average weight | - | - | - | 2.6 | 2.9 | 3.0 | 2.6 |

The variations in the average dimensions[1] of Atlantic salmon in the catches depend on a number of factors. Although females always predominate among the autumn salmon, the ratio of the sexes still varies. The number of females usually fluctuates from 70 to 77%; however, in November 1959 for example, there were 57%

*The length throughout the paper is given from the tip of the snout to the end of the middle rays of the caudal fin.

of them. This affects the average dimensions of the Atlantic salmon, as the females are smaller than the males (table 2).

Table 2. Dimensions of females and males in the catches of 1959

| Date | Sex | Length, cm | Weight, g | n |
|---|---|---|---|---|
| 20-28/XI | Females | 62.4 | 3120 | 207 |
| | Males | 64.2 | 3380 | 63 |
| 1-31/X | Females | 59.4 | 2630 | 398 |
| | Males | 63.4 | 3320 | 99 |
| 4/XI-2/XII | Females | 58.2 | 2440 | 203 |
| | Males | 63.5 | 3220 | 156 |

The average size of an Atlantic salmon entering the river also depends on the ratio of the numbers of individuals with different spans of sea life (table 3).

Table 3. Age composition and average length of autumn Atlantic salmon

| D a t e | Percentage of fish living in the sea for periods of | | | Length, cm (males and females combined) | n |
|---|---|---|---|---|---|
| | 1+ | 2+ | with spawning mark | | |
| 25-30/IX 1954 | 76.5 | 20.5 | 3.0 | 63.0 | 200 |
| 19-24/IX 1957 | 71.4 | 24.2 | 4.4 | 63.8 | 423 |
| 1-19/X 1958 | 98.2 | 1.1 | 0.7 | 58.3 | 543 |
| 22-28/IX 1959 | 63.2 | 24.3 | 12.5 | 63.9 | 136 |
| 12/XI-2/XII 1959 | 97.8 | 1.1 | 1.1 | 60.5 | 274 |

The material used for determining the fecundity of Atlantic salmon from the Varguza R. is shown in table 4. The most accurate results are obtained when fecundity is determined by ovaries at the 4th stage of maturity.

The method of graphical presentation was used to determine fecundity. The same method has been used to determine the fecundity of blue bream (Yurovitsky, 1958) and a number of other fish

(Dryagin, 1952). M.I. Vladimirskaya (1960) has presented the relationship between the fecundity and length of the Atlantic salmon from the Pechora River without taking the logarithm and deriving the mathematical dependence.

The graphical presentation of the relationship between the average fecundity and length of the Atlantic salmon or its formula, which are given in this paper. can be used for annual determination of the fecundity of migratory autumn Atlantic salmon from the Varguza R. on the basis of the average length of the females of this group in the commercial catches.

Table 4. Number of female fish studied

| Year | Month | Group | Stage of maturity | No. of specimens studied for | |
|---|---|---|---|---|---|
| | | | | fecundity | diam. of ovocytes |
| 1954 | September | Winter salmon[1] | IV | 16 | - |
| 1955 | " | Winter salmon[1] | IV | 3 | - |
| 1955 | " | Winter salmon[2] | IV | 7 | - |
| 1959 | " | Winter salmon[1] | IV | 24 | - |
| 1959 | " | Autumn salmon[3] | III | 70 | 71 |
| 1959 | June | Winter salmon[3] | III | 30 | 30 |
| 1959 | July | Grilse[3] | III | 6 | 6 |
| 1959 | " | Summer salmon[3] | III | 102 | 24 |

N o t e: 25 measurements were taken from each fish to determine the mean diameter of the ovocytes. The stage of maturity of the ovaries in Atlantic salmon entering the river is given as III, in accordance to the histologic analyses of L.M. Nusenbaum (1951).

[1]From June to September, the fish were kept in a river enclosure.

[2]From spawning places.

[3]During migration.

The graph in fig. 1 is based on 50 specimens of winter Atlantic salmon with ovaries at the 4th stage of maturity. The winter salmon of the Varguza R. constitutes the remains of the

migration of the autumn salmon, as it overwinters in the lower parts of the river (Melnikova, 1959). The length and fecundity of the females used to derive the unknown dependence are given in table 5. Despite the fact that the material was collected in 1954, 1955 and 1959, the results of the fecundity determinations are quite similar for all three years. This enabled us to derive the fecundity characteristic with a sufficient degree of reliability.

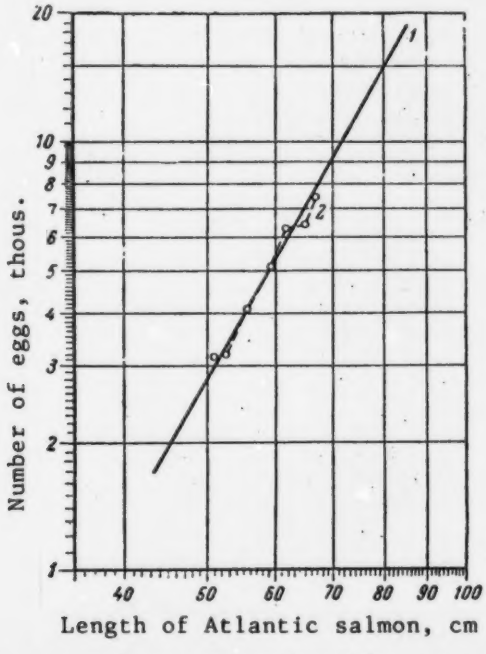


Fig. 1. Fecundity of Atlantic salmon, determined from ovaries at the 4th stage of maturity: 1 - determined by the least squares method; 2 - determined by calculations based on length classes

In fig. 1, the dependence of fecundity on the length of the Atlantic salmon is expressed in the form of a curve which indicates that fecundity increases significantly with an increase in the size of the fish. On a logarithmic scale, this curve approximates a straight line (fig. 1). This stands to reason, as the number of eggs is proportional to the size of the body cavity.

Table 5. Length and fecundity of female Atlantic salmon, on which the graph in fig. 1 is based (ovaries at the 4th stage of maturity)

| Length, cm | Fecundity, no. of eggs | Length, cm | Fecundity, no. of eggs | Length, cm | Fecundity, no. of eggs | Length, cm | Fecundity, no. of eggs |
|---|---|---|---|---|---|---|---|
| 51.0 | 3537 | 54.5 | 2898 | 58.0 | 4571 | 60.0 | 4725 |
| 51.0 | 2866 | 55.0 | 3184 | 58.0 | 5076 | 60.0 | 4810 |
| 51.5 | 3755 | 55.0 | 2885 | 58.0 | 5429 | 60.0 | 4560 |
| 52.5 | 3164 | 55.0 | 4233 | 58.0 | 4935 | 60.5 | 5324 |
| 53.0 | 3452 | 55.0 | 5066 | 58.0 | 6320 | 61.0 | 8132 |
| 53.0 | 2915 | 55.5 | 4259 | 58.0 | 5160 | 62.0 | 6150 |
| 53.0 | 2852 | 56.0 | 3904 | 58.0 | 5715 | 63.0 | 5565 |
| 53.0 | 2599 | 56.0 | 3607 | 58.0 | 4508 | 63.5 | 8550 |
| 53.0 | 3422 | 56.0 | 4950 | 58.5 | 6623 | 63.5 | 5254 |
| 54.0 | 3920 | 56.0 | 3914 | 59.0 | 5034 | 64.0 | 5562 |
| 54.0 | 3750 | 56.5 | 5412 | 59.0 | 4186 | 67.0 | 7580 |
| 54.0 | 3904 | 57.0 | 4380 | 60.0 | 4366 | | |
| 54.0 | 3960 | 57.0 | 4280 | 60.0 | 5445 | | |

If we assume that the fish are geometrically similar, then the correlation between fecundity and length can be expressed by the formula[1] $p = a\ell^3$, since the volume is proportional to the cube of linear size. On the logarithmic scale, this relationship will be a straight-line equation, i.e. $\lg p = \lg a + 3\lg \ell$. (472)

Since no rigid geometric similarity is observed in reality, one can expect fecundity to be proportional not to the cube of the length, but rather to another power similar to the cube, i.e.

$$\lg p = \lg a + b\lg \ell.$$

The value of the coefficients a and b is derived by the least-squares method.

The fecundity of Atlantic salmon from the Varguza R. increases with length according to the formula $p = 0.01011\ l^{3.50148}$, where p denotes the fecundity of the Atlantic salmon, and $\ell$ its length.

Fecundity is calculated by taking the logarithm, i.e.

$\lg p = \lg 0.01011 + 3.50148 \lg \ell$.

The correlation ratio is 0.6.

[1] See footnote on p. 15 - transl.

The same graphical presentation of the relationship between the average fecundity and the length of the Atlantic salmon can also be obtained by another method. With a sufficient amount of material, the second method can produce good results for graphical presentation. In this case, the lengths of the females in which fecundity is being determined are grouped into classes, and then the average fecundity corresponding to each length class is determined (table 6). According to these data, the points are plotted on a graph, and then joined. The average fecundity obtained by these two methods proved to be very similar (fig. 1).

Table 6. Fecundity of the Atlantic salmon according to length classes

| Length class, cm | Fecundity in length classes, no. of eggs | n | Length class, cm | Fecundity in length classes, no. of eggs | n |
|---|---|---|---|---|---|
| 49-51 | 3201 | 2 | 61-63 | 6292 | 4 |
| 52-54 | 3245 | 11 | 64-66 | 6455 | 3 |
| 55-57 | 4075 | 13 | 67-69 | 7580 | 1 |
| 58-60 | 5091 | 16 | | | |

Table 7. Average fecundity of autumn Atlantic salmon, determined by the graph in fig. 1.

| Date of determination of average length of females | n | Length of females in commercial catches, cm | Average fecundity of 1 female (fig. 1) |
|---|---|---|---|
| 25-30/IX 1954 | 164 | 62.2 | 6100 |
| 19-24/IX 1957 | 311 | 63.0 | 6400 |
| 1/X-28/XI 1958 | 946 | 57.1 | 4500 |
| 20-28/IX 1959 | 207 | 62.4 | 6300 |
| 1-31/X 1959 | 398 | 59.4 | 5200 |
| 4/XI-2/XII 1959 | 203 | 58.2 | 4800 |

In an earlier paper (Melnikova, 1959), the average fecundity of an average 58.9 cm winter Atlantic salmon was given as 4700 eggs. This is similar to the values determined by the graph

(table 7), where a fecundity of 4800 eggs corresponds to a length of 58.2 cm. In the first case, we give the average lengths of the females and their fecundity, based on a small number of specimens of different size. This method of determining fecundity has the following disadvantages. The length of the females, similar to their weight (table 1), varies in the catches (table 7). If we determine fecundity by the usual method (i.e. determine the average values of length and fecundity), fecundity will vary according to the length variations from the previously derived value. When determining fecundity by our method, it suffices to establish the average length of the females in the catches. The number of specimens studied in this case can be quite large; however, this would be far more difficult to accomplish if we had to determine the fecundity in each of these specimens. Examples of fecundity determinations by the graph depending on the length of the females in commercial catches are given in table 7.

It is more convenient to determine fecundity when the Atlantic salmon is entering the river also because fishing for this species is not carried out at the breeding grounds in order to preserve as many spawners as possible. At the same time, the determination of fecundity in small Atlantic salmon from the Varguza R. is not accurate enough if it is carried out on the basis of ovaries at the 3rd stage of maturity, i.e. when the fish are entering the river. Since the length of the Atlantic salmon does not change at the spawning grounds, it is convenient to study the length of the females when they are entering the river, and fecundity by the proposed graph or formula.

During graphical presentation of the fedundity-weight dependence as applied, for example, to the blue bream (Yurovitsky, 1958), it takes the form of a straight line. This proved to be inconvenient with respect to the Atlantic salmon, as its weight varies in different groups, and changes significantly by the time it is ready to spawn. The fish at the spawning grounds may be emaciated due to prolonged periods without food in the river and the transfer of trophic substances from the body into the gonads. Therefore, it is difficult to compare the fecundity-weight relationship in specimens collected at different times, as the number of eggs per unit of weight will differ. The length of the Atlantic salmon is a more constant value.

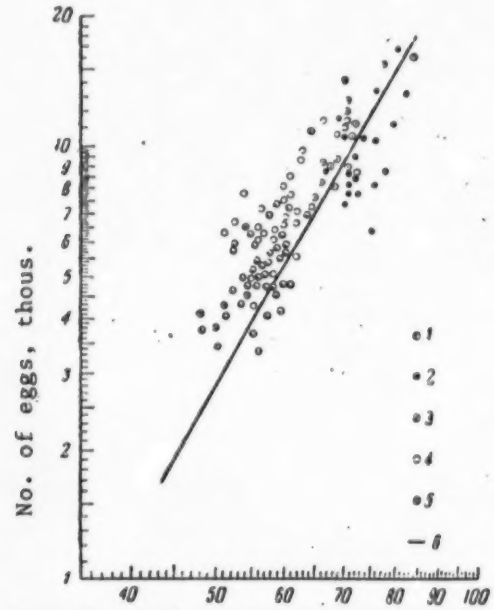


Fig. 2. Fecundity of the "winter salmon", grilse and autumn salmon of Salmo salar L. Determination was carried out as the fish entered the river.

1 - autumn Atlantic salmon which spent 1+ years in the sea; 2 - autumn Atlantic salmon which spent 2+ years in the sea; 3 - autumn Atlantic salmon entering the river to spawn for the second time; 4 - "winter salmon"; 5 - grilse; 6 - average fecundity determined by the least-squares method (from fig. 1)

The straight line in fig. 2 marks the same average fecundity depicted in fig. 1, but also includes the fecundity of autumn (474)
Atlantic salmon caught in September 1959, a winter salmon caught in June, and 6 grilse caught in July. The ovaries of all the female fish were at the 3rd stage of maturity. The data on the fecundity of the larger specimens are distributed more uniformly in relation to the straight line, though the fecundity of the second-time spawners is mainly distributed slightly above the line corresponding to average fecundity. The fecundity of Atlantic salmon smaller than 65 cm proved to be higher than the average fecundity which is marked by a straight line in the diagram. This indicates that the determination of the fecundity of Atlantic salmon on the basis of material collected from the females of autumn salmon, winter salmon or grilse at the beginning of their migration can produce incorrect results.

This can be explained by means of fig. 3 which shows the relationship between the size of the females of autumn Atlantic salmon and the mean diameters of their ovocytes when the ovaries are at the 3rd stage of maturity. Despite the fact that the material was collected at the same time, the diameter of the ovocytes was found to depend on the length of the fish, i.e. the diameter was smaller in the smaller specimens, and larger in the larger ones. Excessively high results are obtained when fecundity is determined by the small ones. This type of relationship between ovocyte diameter and fish length has been noted by a number of authors (Berg, 1935; Suvorov, 1948; Dryagin, 1952; Novikov, 1953).

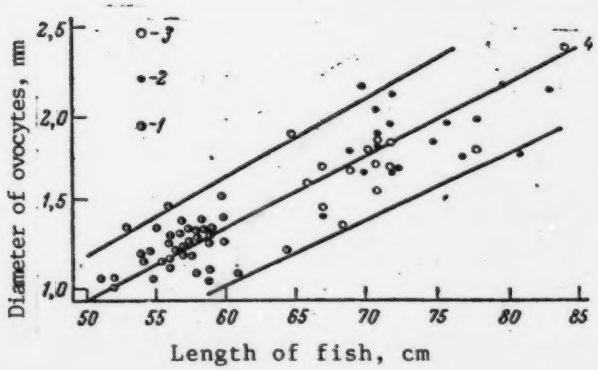


Fig. 3. Relationship between the diameter of the ovocytes of autumn Atlantic salmon and its length as it enters the river

1 - diameter of ovocytes in specimens that had lived in the sea for 1+ years; 2 - the same for specimens that had lived in the sea for 2+ years; 3 - the same in second-time spawners; 4 - mean diameter of ovocytes

The fecundity in larger specimens of autumn Atlantic salmon which are far from the spawning stage is already similar to the fecundity established in the same kind of autumn salmon at the 4th stage of maturity of the ovaries. This type of concurrence is not observed in small specimens with an ovocyte diameter of up to 1.5 mm. When fecundity is determined on the basis of such specimens, some of the ovocytes are miscounted, those which in ovaries from the 4th stage of maturity will not be miscounted, since they stop growing or, perhaps, undergo atresia in the course of their development. In our case, this was particularly manifest in the winter salmon in 1959; in one and the same batch of females, fecundity was determined in June (when they were placed in a fish-breeding pond) and in September in ovaries from the 4th stage of maturity. Fecundity proved to be higher in the first case, than in the second. In fig. 2, almost all the fecundity values for the winter salmon in June are found above the straight line that

corresponds to the average fecundity of Atlantic salmon with ovaries at the 4th stage of maturity.

(475)

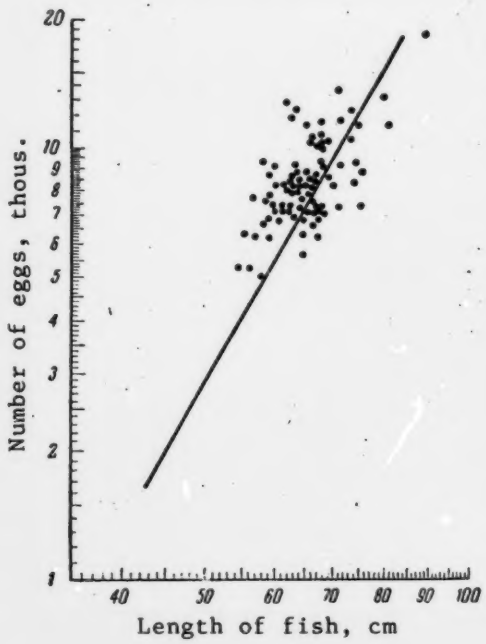


Fig. 4. Fecundity of "summer salmon", determined during entry into the river. Black dots denote the fecundity of the summer salmon; the straight line denotes the average fecundity determined by the least-squares method (from fig. 1)

During histologic analyses of ovaries from the Atlantic salmon of the Varguza R., L.M. Nusenbaum (1951) noted significant asynchrony in ovocyte development in the autumn salmon when it entered the river. The ovaries at this time were at the beginning of the 3rd stage of maturity. This asynchrony disappears by the time the fish is ready to spawn. During this asynchrony in the development of the ovocytes, it is sometimes difficult to differentiate those which will be deposited first.

The straight line in fig. 4 shows the average fecundity of the Atlantic salmon, determined from ovaries at the 4th stage of maturity (from fig. 1), while the black dots denote the fecundity

of summer salmon with ovaries at the 3rd stage of maturity. The ovocytes are larger in the females of the latter group (material collected later); their diameter in June-July varied from 1.26 to 3.55 mm (average 2.35 mm). The average fecundity of the summer salmon should be closer to the fecundity determined prior to spawning. However, as we can see from fig. 4, the average fecundity of the small specimens of summer salmon can also be slightly overstated when ovocytes visible to the naked eye are counted.

Other authors have also noted the presence of small eggs alongside large ones in the ovaries. A.M. Gulyayeva (1950) specifies that small eggs were not taken into account when determining fecundity in autumn Atlantic salmon. There are fewer small eggs in the summer Atlantic salmon. With this approach to determining fecundity, it is difficult to tell which eggs should be counted, and which ones should be overlooked, as this depends on the researcher's personal opinion.

Comparing the fecundity of Pechora Atlantic salmon determined in fish entering the river in autumn with that of spawned out fish, P.I. Novikov (1956) notes that although the material was collected during different years, there was a great difference in the value of fecundity only in 2-3 kg specimens. The average weight of an Atlantic salmon from the Pechora River is 6 kg. Most of the Varguza stock of Atlantic salmon consists of 2-3 kg fish, and so excessively high results are obtained when fecundity is determined on the basis of autumn Atlantic salmon in which the gonads are at the 3rd stage of maturity.

The fecundity of Varguza Atlantic salmon is smaller than that of the Atlantic salmon of other rivers; it averages 8015 eggs in the Ponoi R. (Smirnov, 1935), 8500 eggs in the Kolvitsa R. (Azbelev, Gromov and Lagunov, 1958), and significantly higher in other rivers, i.e. 12,500 in the Voron'ya R., 12,300 in the Pinega R., 10,800 in the Solyana R. and 19,000 in the Onega R. (Berg, 1935).

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[1] According to Huxley's theory (Terent'yev, 1945), in the vast majority of cases, the overall dimensions (length, volume or weight) of the whole body or any part of it can be correlated by the equation $y = bx^{\alpha}$; y denotes the dimensions of the part, and x the dimensions of the whole body or "standard" measurement; coefficient b gives the value of y when x=1. In our case, the exponent $\alpha$ is given as b.